Comparing aerobic intervals and general multi-skill activities and their effect in improving aerobic performance in prepubertal children

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This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

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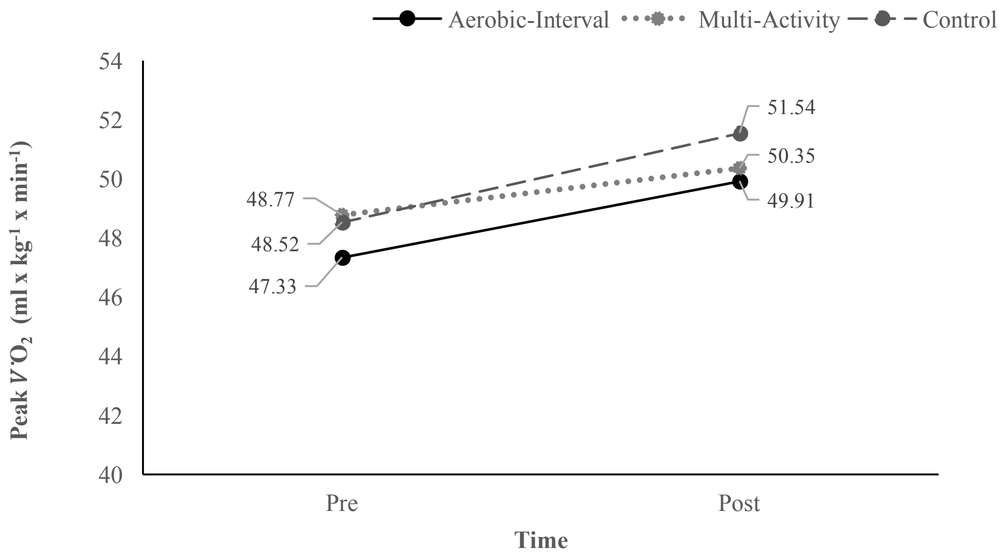

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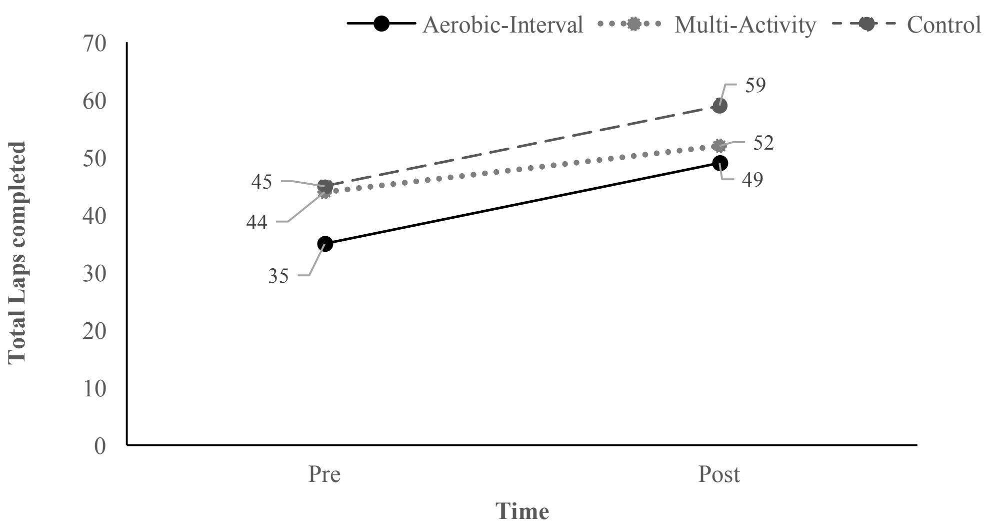

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Table 1. Details of the 8-week training sessions for the aerobic-interval group

Aerobic- interval group training sessions over eight weeks. The training sessions applied a minimal intensity of 8 out of 10 effort, with short rest periods, under 45-seconds. Running and sprinting were the main mode of training in the form of relay races and shuttle runs.	
Week	**Training Details**
1 and 2	20 metre sprint (relay) x 4 10 metre sprint (relay) x 5. Participant starts as team participant returns 20 metre run x 5 star jumps (relay) x 5 Bean bag throw, sprint 10 metres pick up bean bag on the way back (race) x 4
3 and 4	20 metre sprint (relay) x 4 10 metre sprint (relay) x 5. Participant starts as team participant returns 10 metre run and tummy lie down x 5 Bean bag throw, sprint 10 metres pick up bean bag on the way back (race) x 4
5 and 6	20 metre sprint (relay) x 4 10 metre sprint (relay) x 5 10 metre sprint/ backwards 5 metre/ sprint 20 metre x 3 10 metre run and tummy lie down x 5 Ball roll, sprint 20 metres, pick up the ball on the return (race) x 4
7 and 8	20 metre sprint (relay) x 4 10 metre sprint (relay) x 5 10 metre sprint/ backwards 5 metre/ sprint 20 metre x 3 10 metre run and tummy lie down x 5 Ball roll, sprint 20 metres, pick up the ball on the return (race) x 4

Table 2. Details of the 8-week training sessions for the multi-activity group.

Multi-skill group training sessions over eight weeks. The training sessions consisted of different activities and games that incorporated a range of the fundamental movement skills. The intensity was kept high and the structure of the games and activities were stop-start in their method.	
Week	**Training Details**
1 and 2	Multi-directional box game. 30x30 square. Participants side shuffle around square and sprint through gate when open. Back to side shuffle for active rest. Same game but sprint through two gates. Pair up participants' coach to call number, when number called the participant tries to run through gates, their partner tries to tag them before making it to the gates. Dodge activity – participants dodge and weave and try to pass through 15 gates before the coach stops the game.
3 and 4	Jumping activities. Jumping relay, broad jump x 1 run 15-20 metres and hop back x 5. Jump x 2 run 10 metres and hop back. Jump game challenge. Jump and land on one foot, jump again on two feet x5 run 10 metres. Team challenge first team to jump 20 metres as a team.
5 and 6	Multi-directional box game. 30x30 square. Participants side shuffle around square and sprint through gate when open. Back to side shuffle for active rest. Same game but sprint through two gates. Pair up participants' coach to call number, when number called the participant tries to run through gates, their partner tries to tag them before making it to the gates. Dodge activity – participants dodge and weave and try to pass through 15 gates before the coach stops the game.

7 and 8	Split the group into higher and lower ability. 2 teams played capture the flag; movement game which includes erratic movement of the participants and short rest periods. The other 2 teams played dodge ball. When the participant got hit by the ball they performed an active movement rather than sitting x 5, then rejoined the game. The teams rotated the games.

Table 3. Mean, ± SD results pre-and-post training. Weight, BMI, and body fat.

Aerobic Interval Group					
	Pre-test		Post-test		Diff
	Mean	**± SD**	**Mean**	**± SD**	
Weight (kg)	30.70	6.6	30.6	6.6	-0.1
BMI (kg / m^2)	16.7	3.2	16.8	3.3	0.1
Body fat (%)	22.1	5.9	22.0	5.9	-0.1
Multi Activity Group					
	Pre-test		Post-test		Diff
	Mean	**± SD**	**Mean**	**± SD**	
Weight (kg)	31.6	4.2	31.7	4.35	0.1
BMI (kg / m^2)	17.2	1.4	17.1	1.5	-0.1
Body fat (%)	16.9	3.7	16.9	3.6	0.0
Control Group					
	Pre-test		Post-test		Diff
	Mean	**± SD**	**Mean**	**± SD**	
Weight (kg)	32.9	5.1	32.6	5.0	-0.3
BMI (kg / m^2)	17.6	2.6	17.3	2.7	-0.3
Body fat (%)	19.12	7.7	19.1	7.7	-0.02

ACKNOWLEDGEMENTS

I would like to firstly thank my thesis supervisor, Dr Stephen Patterson of Twickenham University for his guidance and support. Secondly, I would like to thank all the sport coaches and teachers who were involved in this project. Finally, I would like to thank my Mother for her constant support and encouragement. This accomplishment would not have been possible without them. I thank you all.

ABSTRACT

The aim of this study was to investigate the effects of aerobic performance in prepubertal children, using specific aerobic-interval training versus a multi-activity games approach over eight-weeks. Thirty-three children, 16 boys and 17 girls (8.4 ± 0.5 years), were randomly assigned to either a specific aerobic-interval group (SAI), multi-activity group (MA), or a control group (CG). The SAI performed high-intensity (minimal 80% effort, monitored using the OMNI scale 0-10, a rate of perceived effort) running, and sprint relays (5-20 metres) with short rest periods (under 45 seconds), to specifically target the aerobic system. The MA performed a range of games (invasion, tag, ball games) incorporating the fundamental movement skills (FMS). The structure of the games controlled the intensity and rest periods. Both the SAI and MA were performed as part of the PE lessons at the participant's school once a week for eight weeks. Pre-and post-training, all participants performed the 20-multistage shuttle run (20-MSR) to calculate peak $\dot{V}O_2$ scores. Post testing, all groups reported improvements in peak $\dot{V}O_2$ SAI (+5%), MA (+3%), and CG (+6%), however no significant differences between the groups (p = .62), as a time effect (p = 0.05) or interaction effect (p = .88) were reported. The total laps completed in the 20-MSR demonstrated a significant difference, as a time effect post training in all three groups, SAI (+38%), MA (18%), and CG (33%) (p = .01). No significant differences were demonstrated between groups (p = .17) or as an interaction effect (p = .82). It was concluded that MA games are comparable with SAI training in improving the aerobic performance in prepubertal children.

Keywords: Fitness, games, intensity, running, training.

INTRODUCTION

National governing bodies and health associations are recommending that children should participate in sixty-minutes of physical activity per day (46, 11, 65). This recommendation is due to the physical, mental and social health benefits promoted by physical activity (55, 25, 60). Schools try to adhere to this recommendation by encouraging physical activity at breaks and lunchtimes, along with traditional physical education (PE) lessons. The PE lessons help to promote physical activity in children, but also have an important role in preparing children to stay active as they age and to participate in recreational sports (57).

There is a debate and some level of ambiguity within the physical development of children, as the recommendation of participating in sixty-minutes of physical activity per day does not specify the mode or type of activity (41). Additionally, the National Curriculum in the UK (47) states that the children should be exposed to a range of sports, to learn a range of movement skills and to develop the fitness components, strength, coordination, control, and balance; however, the curriculum does not give any guidance in regard to the frequency, intensity or duration. Moreover, there is no mention of developing aerobic fitness. This is surprising, as there are numerous reported benefits for aerobic training in children, including aiding in body fat reduction (64), improved cognitive function (22), and helping to manage insulin levels (43). It may not come as a surprise that some schools are now adopting the one-mile strategy to improve aerobic fitness in young children (51, 53).

Early studies were inconsistent within their findings surrounding improvements in aerobic adaptations, especially in prepubescent children; the development years before puberty, under 11-years-old in girls and under 13-years-old in boys (1). Kobayashi et al. (27) reported no significant aerobic improvements in younger children; under 13-years old, whereas boys aged between 13–17 years-old improved their aerobic capacity from 45.0 to 52.2 ml x kg^{-1} x min^{-1}. Mirwald et al. (38) also reported no significant changes in aerobic capacity before puberty, but reported significant changes within the stage of peak height velocity. This suggests that there was an actual threshold in prepubescent children's physiology, with the children's physiology becoming more sensitive to aerobic training as they moved into puberty (20). Conversely, in a review completed by Vaccaro et al. (59) the authors analysed both cross sectional and longitudinal studies and reported that prepubertal children can improve their aerobic capacity when the training principles are applied. This was supported by Rowland et al. (54), where the authors completed a critical review of aerobic responses in prepubertal children. Rowland concluded and agreed with Vaccaro, as six of the eight studies that meet the training guidelines reported significant improvements in aerobic capacity. This discrepancy within the literature surrounding early aerobic adaptations may be due to the study design, such as the starting aerobic fitness levels, training age of the participants and intensity or mode of training. A more recent review of the aerobic and endurance training in young people completed by Baquet at al. (7) reported that prepubertal children can improve their peak $\dot{V}O_2$ by 5-6% when the training variables are applied. Baquet confirmed that studies that reported significant differences applied a training duration of 30-60 minutes, a training frequency of 3–4 sessions per week, and a minimal training intensity of 80% maximal heart rate. Baquet did conclude that a training frequency of twice a week may be sufficient, and the key element to gain an aerobic response was due to the training intensity. This was demonstrated in a study completed by Baquet et al. (6), where the researchers significantly improved the aerobic capacity in 8-11-year-olds using a 30-minute sprint training programme twice a week. The intensity was controlled by running speeds, 110-130% maximal aerobic speed for distances of 10-20 seconds. The training programme progressed throughout the 7 weeks using the running speeds to gain an overload response. McNarry et al. (36) also demonstrated that aerobic capacity can be progressed over three years using a longitudinal study design. McNarry tested 19 trained and 15 untrained swimmers of ages between 9-10 years old. Re-testing the swimmers over the three years, McNarry reported that the trained swimmers significantly demonstrated improvements in their aerobic capacity compared to the untrained group. The intensity of the training sessions was not reported, however, the training volume increased over the three years. This growing body of evidence confirms that young children of all ages can improve their aerobic capacity and refutes the training threshold theory.

On the other hand, and aligned with the PE national curriculum, studies have reported the importance and benefits of children learning and mastering the FMS (41, 24). The FMS are categorised as locomotor, body control and object control. Through exposing children to a range of FMS, it has been suggested that it sets a bedrock to participate within sports and acts as a catalyst to adopting an active lifestyle into adulthood (8). The FMS are emphasised and embedded with the Youth Development Model (YDM) (29), where the authors recommend a concurrent training approach to learning of the FMS along with the development of strength, agility, power and mobility. Interestingly, the YDM does not recommend any specific aerobic training before puberty and states that aerobic training can be enhanced indirectly by playing multi-activity games and sports. Faigenbaum et al. (15) reported both physical and skill improvements by prescribing 15-minutes of strength and skilled based exercises to 9–10-year-old children. The training programme replaced the first quarter of their regular PE lesson, and was performed twice a week for eight weeks. Faigenbaum reported improvements in push-ups, flexibility, single hop and aerobic capacity, even though the children did not engage in aerobic training. Neuromuscular adaptations can explain the improvements in the push-ups and single hop (49, 26), furthermore it may also explain the change in aerobic performance via better running economy (28, 40), especially as the starting aerobic fitness levels were not stated.

Other studies have also reported improvements in both strength and endurance in children when a circuit-type training approach is prescribed (16, 33), however, the exercises that are being implemented within the interventions need to be considered, as traditional gym-based exercises like biceps curls, triceps extensions and abdominal crunches may not fall into the bracket of true FMS (18). The FMS are based upon dynamic movements such as, running, jumping, leaping, turning (locomotor), stopping, landing, dodging (body control), throwing, catching and striking (object control) or a multi-activity approach. The importance of learning and mastering the FMS is through acquiring a broad range of skills rather than exercising; as children are not mini adults, and their reason for being active is to engage with their friends and to have fun.

As the body of evidence supports both the learning of the FMS and the inclusion of aerobic training in children, this study will explore the YDM recommendation of using a multi-activity approach to improve aerobic fitness in children. The YDM is based upon a theoretical model and evidence is lacking to support it. Hence, this study will investigate the aerobic improvements in prepubertal children comparing specific aerobic interval training versus multi-activity training, along with regular PE lessons, which will act at the control group. The hypothesis is that the specific aerobic interval training will show higher levels of peak $\dot{V}O_2$ improvements compared to the multi-activity and control group.

METHODS

Experimental Approach to the Problem

A randomised control trial study design was used where participants were assigned to one of three groups; (a) specific aerobic-interval (SAI), (b) multi-activity (MA), or (c) a control group (CG). All participants attended the same school and were in the same year. It is reported that whole-class participation is randomly assigned (13, 7), however, to prevent any bias the three classes that participated in the study were randomly assigned to a group by a computerised number selection. The total duration of the study was ten-weeks, with weeks one and ten being used for the pre-and-post testing. Participants in the SAI performed mostly running, relays and sprint activities that stimulate the aerobic system. The intensity of the session was measured using the OMNI scale; a verbal and pictorial rate of perceived exertion developed for children under the age of 11 years old. The OMNI scale is presented in a simple format of 0 = no effort, 5 = tired to 9 and 10 = very, very tired. Utter et al. (58) measured the correlation using the OMNI scaled against a graded exercise test ($\dot{V}O_{2max}$) in children 6–13 years and reported an average but consistent linear relationship (R = 0.41 – 0.60). All participants were familiarised to the OMNI scale before each session and the participants gave verbal feedback on their effort level. The participants in the MA group were exposed to a range of movement skills in the form of group activities and games. The natural competitive aspect of the activities and games kept the effort levels high. The CG continued to perform their regular PE lessons. The 20-MSR was performed by all participants to calculate their starting peak $\dot{V}O_2$. The 20-MSR is commonly used when testing large groups (44, 45), and has been validated as a reliable test, r = 0.73 boys and r = 0.88 girls (30). Anthropometrics, height, bodyweight and body fat were also recorded.

Subjects

Thirty-three prepubescent school children participated in the study 16 boys and 17 girls (8.4 ± 0.5 years; 31.7± 5.3kg; 1.36 ± 0.05cm; 19.4 body fat ± 5.3%; 17.1 ± 2.4 kg / m^2) (sample size estimate = 74). The study was designed in accordance with the ethical standards of the Helsinki Deceleration of 1975 and received approval from the ethical committee board, St Mary's Twickenham University, London. Before the start of the study, all parents and participants received an information sheet which clearly explained the aims of the study. The participants and parents read through the information sheet and the participant's parents signed the informed consent form giving permission for their child to participate in the study.

Procedures

The anthropometrics, height, weight and body fat were taken from all the participants pre-and post-testing. The height was taken using a height measure metre (Marsden HM-250P Leicester, Oxon, UK) following the recommended guidelines; shoes were removed and participants were instructed to stand with good posture. Measurements were taken to the nearest cm. Body mass and body fat were measured using a body composition monitor (Omron body composition HBF-511b-E Japan). The body mass was recorded to the nearest kilogram (kg) and body fat was recorded as a percentage of body mass. The participant's body mass index scores (BMI) were calculated using the standard calculation (body mass kg / height m^2).

Before starting the aerobic fitness testing, all participants were familiarized with the 20-MSR and any questions from the participants were answered. The 20-MSR was performed pre-and post-training outside using a multi-sports court located in the school's grounds. The court was free from any obstacles and the ground was dry and non-slippery. The 20-metre distance was clearly marked by cones and the audio was played using a portable sound-system. The participants' objective was to run between the two lines of cones, 20-metres apart in time with the pre-recorded audio beeps using a maximum effort. At the command "go" the participants started to run from the 0 line to the 20metre line and back again to the sound of the beep, which was playing to a set tempo and controls the running speed; a coach completed the first few laps with the participants to reduce any confusion. The running speed in the 20-MSR starts at 8.5 km/h and increases an additional 0.5 km/h after each minute. The participants attempted to run, keeping in time with the beep, increasing their speed as the beep changed. Visual and vocal encouragement were used to motivate the participants to work to voluntary exhaustion and the change of each level was vocalized to add motivation. The last stage was noted at the point where the participant failed to cross the 0 or 20 metre line and was recorded as their total laps completed. As the participants dropped out of the 20-MSR they were physically exhausted, showing signs of sweating and redness in the face that confirmed their effort level. The equation from Matsuzka et al. (32) was used to calculate the participant's peak $\dot{V}O_2$, as the authors compared the calculation to a laboratory graded treadmill test and reported a strong relationship (R =0.77 - 0.87) (R^2 =.80, SEE=3.4 ml x kg^{-1} x min^{-1}). Peak $\dot{V}O_2 = 61.1 - 2.20 \cdot gender - 0.462 \cdot age - 0.862 \cdot BMI + 0.192 \cdot TL$ (gender female=0 male =1, TL =total laps).

The school performed two PE lessons per week, over the eight-weeks the experimental group SAI and MA utilized one of the PE lessons per week to complete their training sessions, performed either on a Tuesday morning or Tuesday afternoon. The second PE session was dedicated to participating in traditional school sports, football, cricket and rugby. All PE sessions were performed within the school's grounds using outside facilities, either the playing field or the outside multi-basketball court. As the whole year perform their PE lesson at the same time, the PE lessons were supervised by qualified coaches and supported by teaching assistants. A normal PE lesson lasts sixty minutes, however, the practical PE lesson was thirty to forty minutes in duration, as the children need time to change. Each coach was assigned a specific group (SAI, MA or CG) and the same coach delivered the PE lesson to that group over the eight-weeks. Before starting the main PE lesson, the coaches explained the objectives to the participants and before starting the physical activities the coaches used a five-minute tag or invasion game as a warm up.

In the SAI group, the main mode of training was sprinting and running in the form of shuttle runs and relay races. To prevent boredom some other movements were used to keep the participants interested, however, the intensity was kept at a high level. The SAI sessions utilised different distances between 5-20 metres and the rest period was performed as the participants finished their sprint and returned to the back of their team. To aid in motivation, equipment (bean bags and balls) were used, this also helped to keep the intensity high. The coach reinforced that the participants should work as hard as possible and explained the OMNI scale in a simple format; indicating that the participants should try to work at a minimum eight out of ten. Using the 0–10 scale, the participants gave verbal ratings throughout the training session. The training sessions did change through the eight-weeks via a variation of sprint and run challenges, as it was also important that the participants enjoyed the training sessions. The SAI sessions lasted a minimum of 30 minutes and are presented in Table 1.

Table 1. Details of the 8-week training sessions for the aerobic-interval group

Aerobic- interval group training sessions over eight weeks. The training sessions applied a minimal intensity of 8 out of 10 effort, with short rest periods, under 45-seconds. Running and sprinting were the main mode of training in the form of relay races and shuttle runs.	
Week	**Training Details**
1 and 2	20 metre sprint (relay) x 4

	10 metre sprint (relay) x 5. Participant starts as team participant returns 20 metre run x 5 star jumps (relay) x 5 Bean bag throw, sprint 10 metres pick up bean bag on the way back (race) x 4
3 and 4	20 metre sprint (relay) x 4 10 metre sprint (relay) x 5. Participant starts as team participant returns 10 metre run and tummy lie down x 5 Bean bag throw, sprint 10 metres pick up bean bag on the way back (race) x 4
5 and 6	20 metre sprint (relay) x 4 10 metre sprint (relay) x 5 10 metre sprint/ backwards 5 metre/ sprint 20 metre x 3 10 metre run and tummy lie down x 5 Ball roll, sprint 20 metres, pick up the ball on the return (race) x 4
7 and 8	20 metre sprint (relay) x 4 10 metre sprint (relay) x 5 10 metre sprint/ backwards 5 metre/ sprint 20 metre x 3 10 metre run and tummy lie down x 5 Ball roll, sprint 20 metres, pick up the ball on the return (race) x 4

The MA sessions were designed to expose the participants to a range of movements through playing different games and activities. The main movement skills used were hopping, skipping, jumping, back peddling, dodging and running, however, with some of the games the participants had a free-range of what movement to use. The coach set up each activity or game and explained the rules to the participants and after starting the game allowed the activity or games to naturally develop. The participants demonstrated a high level of effort through the games, especially in the invasion games, such as capture the flag and dodge-ball. Additionally, the coach would ask the participants to complete a low-level activity when they "got tagged" for example, so that the rest, was an active rest and the games and activities adopted a stop-start approach. This was also applied in the ball games. The duration of MA training sessions also lasted a minimal of 30-minutes and details of the activities are presented in Table 2.

Table 2. Details of the 8-week training sessions for the multi-activity group.

Multi-skill group training sessions over eight weeks. The training sessions consisted of different activities and games that incorporated a range of the fundamental movement skills. The intensity was kept high and the structure of the games and activities were stop-start in their method.	
Week	**Training Details**
1 and 2	Multi-directional box game. 30x30 square. Participants side shuffle around square and sprint through gate when open. Back to side shuffle for active rest. Same game but sprint through two gates. Pair up participants' coach to call number, when number called the participant tries to run through gates, their partner tries to tag them before making it to the gates. Dodge activity – participants dodge and weave and try to pass through 15 gates before the coach stops the game.
3 and 4	Jumping activities. Jumping relay, broad jump x 1 run 15-20 metres and hop back x 5. Jump x 2 run 10 metres and hop back. Jump game challenge. Jump and land on one foot, jump again on two feet x5 run 10 metres. Team challenge first team to jump 20 metres as a team.
5 and 6	Multi-directional box game. 30x30 square. Participants side shuffle around square and sprint through gate when open. Back to side shuffle for active rest. Same game but sprint through two gates. Pair up participants' coach to call

	number, when number called the participant tries to run through gates, their partner tries to tag them before making it to the gates. Dodge activity – participants dodge and weave and try to pass through 15 gates before the coach stops the game.
7 and 8	Split the group into higher and lower ability. 2 teams played capture the flag; movement game which includes erratic movement of the participants and short rest periods. The other 2 teams played dodge ball. When the participant got hit by the ball they performed an active movement rather than sitting x 5, then rejoined the game. The teams rotated the games.

Statistical Analysis

The descriptive statistical values are expressed as a mean and standard deviation (±). A one-way analysis of variance (ANOVA) was performed pre-testing to confirm that no significant differences were between the three groups in the anthropometry and starting aerobic fitness levels. Post-testing and to analyse the effects of the training programmes for significant difference, a two-way ANOVA with replication was used (time/pre/post x groups/multi/aerobic/control). The statistical significant alpha was set at $p \leq 0.05$.

RESULTS

Pre-training, the one-way ANOVA reported no difference among the groups at baseline on, height, bodyweight, BMI, body fat, peak $\dot{V}O_2$ F (2, 32) = 0.33, p = .72 and total laps completed F (2, 32) = 1.17, p .32. Analysis of post-testing, using a two-way ANOVA with replication presented no significant differences between the groups on height, bodyweight, BMI, and body fat (Table 3). Analysis of pre-and post-testing reported no significant interaction effect F (2, 60) = 0.13, p = .88. The analysis between the groups reported an increase in peak $\dot{V}O_2$ in all three groups (Figure 1), SAI (47.33 to 49.91 ml x kg^{-1} x min^{-1}), MA (48.77 to 50.35 ml x kg^{-1} x min^{-1}), and CG (48.52 to 51.54 ml x kg^{-1} x min^{-1}), however no significant differences were found F (1, 60) = 0.47, p = .62. Analysis of pre-and-post testing time effect between the groups reported no significant differences F (1, 60) = 3.98, p = .05. Pre-and-post testing of the total laps completed in the 20-MSR, the ANOVA did not report a significant interaction effect F (2, 60) = 0.20, p = .82, and no significant difference between groups F (2, 60) = 1.83, p = .17. However, there was a significant difference in a time effect in all three groups (Figure 2), F (1, 60) = 7.09, p = .01. There was a moderate size effect calculated by η^2 in all three groups (SAI = 0.67, MA = 0.47, CG = 0.81). The positive effect in the CG was not expected.

Table 3. Mean, ± SD results pre-and-post training. Weight, BMI, and body fat.

Aerobic Interval Group					
	Pre-test		Post-test		Diff
	Mean	**± SD**	**Mean**	**± SD**	
Weight (kg)	30.70	6.6	30.6	6.6	-0.1
BMI (kg / m^2)	16.7	3.2	16.8	3.3	0.1
Body fat (%)	22.1	5.9	22.0	5.9	-0.1

Multi Activity Group					
	Pre-test		Post-test		Diff
	Mean	**± SD**	**Mean**	**± SD**	
Weight (kg)	31.6	4.2	31.7	4.35	0.1
BMI (kg / m^2)	17.2	1.4	17.1	1.5	-0.1
Body fat (%)	16.9	3.7	16.9	3.6	0.0
Control Group					
	Pre-test		Post-test		Diff
	Mean	**± SD**	**Mean**	**± SD**	
Weight (kg)	32.9	5.1	32.6	5.0	-0.3
BMI (kg / m^2)	17.6	2.6	17.3	2.7	-0.3
Body fat (%)	19.12	7.7	19.1	7.7	-0.02

Figure 1. Pre-and-post results of peak $\dot{V}O_2$ in all three groups (SAI, MA, CG).

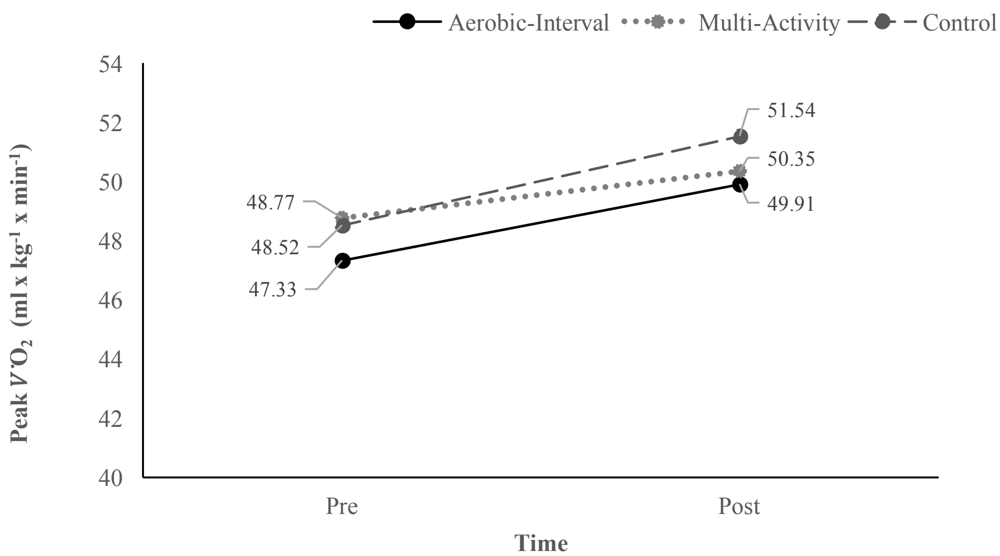
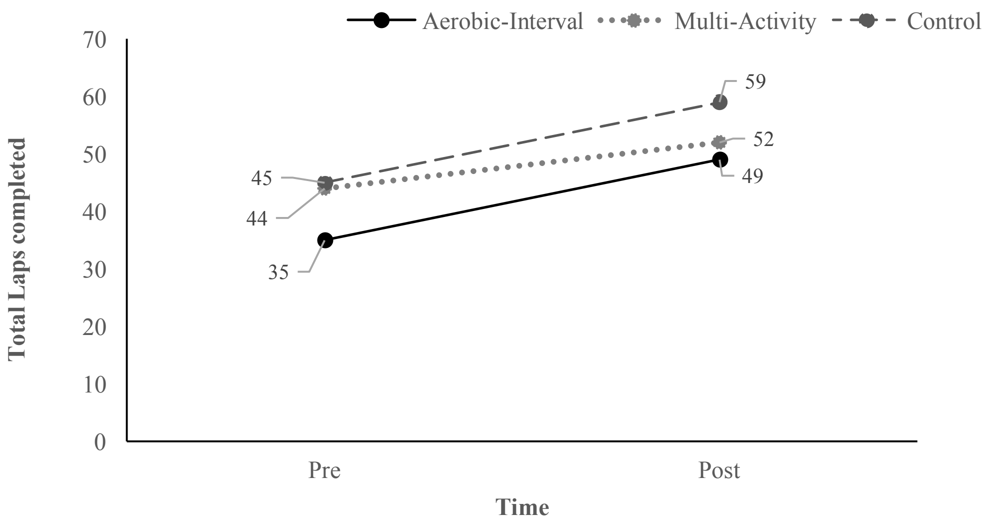


Figure 2. Pre-and-post results of total laps completed. All three groups reported a significant difference



DISCUSSION

The main findings from this study, was that an eight-week training programme using specific aerobic-interval or a multi-activity approach implementing games and activities designed using the FMS, improved the aerobic fitness level of prepubertal children. The CG also improved their aerobic fitness levels from 48.52 to 51.54 ml x kg^{-1} x min^{-1}, which is inconsistent with previous studies, as other studies have criticised traditional PE lessons for not improving overall fitness levels (9 ,61). Morgan et al. (39) reported that 56% of primary school teachers did not feel confident in delivering PE lessons due to a lack of technical knowledge, whereas in this current study, PE specialists delivered and coached all the PE lessons. Additionally, an analysis of frequency and intensity within 9-year-olds' PE lessons, reported that each child averages 2.1 PE classes per week, lasting 33 minutes. Of the 33 minutes, only 4.8 minutes were recorded as being high intensity with the remaining 28.2 minutes being recorded as moderate to low intensity (42). Furthermore, the analysis identified significant changes in intensity comparing indoor and outdoor PE lessons (indoor sitting 10.2 compared to outdoor sitting 3.0 minutes). As the school of this current study utilised the eight weeks to incorporate their athletic term outdoors, along with the PE lessons being coached by qualified staff, this increase in activity compared to sitting, and higher intensity levels from running and sprinting, would put more of a demand on the aerobic system, and may explain the aerobic improvements demonstrated within the CG.

The SAI improved their aerobic fitness which is consistent with other studies (4, 14, 34). The MA also improved their aerobic fitness, which is difficult to compare as many studies have examined the effects of strength and aerobic improvements in children using a range of specific modes of training, bodyweight strength exercises (17), circuit training (33), and plyometrics (16), however, only a few studies have used non-specific games or activities as their main intervention. McNarry et al. (35) reported cardiovascular improvements in overweight children compared to normal weight children, using high-intensity games performed twice a week for six-weeks. The cardiovascular improvements were reported to be a change in the $\dot{V}O_2$ kinetics, which are described as the small adjustment in the phase of oxygen delivery relative to a change in metabolic rate (62). Consequently, the overweight children's $\dot{V}O_2$ kinetics became more comparable to the normal weight children, whereas the normal weight children did not show any difference in $\dot{V}O_2$ kinetics or peak $\dot{V}O_2$. The $\dot{V}O_2$ kinetics changes are suggested to be more peripheral than central adaptations (48), however, the evidence surrounding the central and peripheral adaptations in young children is lacking. Meredith et al. (37) reported minimal peripheral adaptations in the skeletal muscle with trained young children, and suggested that changes in cardiac output and an altered stroke volume may result in an increase in peak $\dot{V}O_2$. This may explain why the study only reported aerobic improvements in the overweight children and not in the normal weight children. Moreover, the normal weight children's starting fitness level was much higher than the overweight children's starting fitness level, 57.2 ml x kg^{-1} x min-^{1} versus 45.6 ml x kg^{-1} x min^{-1} respectively. The overweight children's starting fitness level was comparable with this current study (48.21 ml x kg^{-1} x min^{-1}), which may explain why both studies reported aerobic improvements. An explanation of why the normal weight children did not improve their aerobic fitness may also come from how the games and activities were prescribed. McNarry, described the games as high-intensity, yet the actual intensity of the training sessions was not reported, even though heart rates were monitored, furthermore, the rest periods were reported at 2-minutes. Studies have shown that young children can recover more quickly than teenagers and adults (50) when generating submaximal forces, due to the oxidative system more being efficient, which may result in less lactic acid accumulation (21). Thus, prescribing long rest periods is less of a demand on the pulmonary and vascular systems. The longer rest periods may explain why the normal weight children did not improve their aerobic fitness, due to reducing the intensity and affecting the training volume. Prescribing, shorter rest periods in the games may have resulted in aerobic improvements in the normal weight children, as reported in this current study.

This suggests that the starting aerobic fitness level, training background, and body mass of young children are factors and may indicate the possible aerobic adaptations and studies need to be careful how they interpret peak $\dot{V}O_2$ improvements. Peripheral adaptations may be the first stage to improving aerobic fitness, followed by central adaptations, as reported in trained children. Therefore, young children who are overweight with no training background and with a low starting fitness level may not result in rapid changes in peak $\dot{V}O_2$, whereas young children with extremely high starting peak $\dot{V}O_2$ scores may not show any peak $\dot{V}O_2$ changes if the intensity is too low or if the testing of peak $\dot{V}O_2$ does not allow some expression of performance characteristics. Aerobic fitness and aerobic performance may not be synonymous in young children and using these interchangeably may lead to confusion. An example of changes in aerobic fitness is demonstrated in a study completed by Baquet et al. (5) who reported peak $\dot{V}O_2$ improvements in prepubertal children who performed 2 x 30 minutes' extra fitness sessions per week over seven weeks. The children in the high-intensity sprint training increased their peak $\dot{V}O_2$ by 5.1%, whereas the children in the control group reported no differences. The researchers managed the study well, monitoring the intensity and rest periods along with changes in the energy costs of running. Interestingly, the researchers did not report any changes in the energy cost of running even though the children were performing running as their main mode of training and the researchers used the 20-metre multistage shuttle run test to calculate the children's peak $\dot{V}O_2$. However, reviewing the participant's starting fitness levels, the average fitness level was below average (43.9 ml x kg^{-1} x min^{-1}). This may highlight that the participants gained both peripheral and central adaptations to improve their peak $\dot{V}O_2$, however, their aerobic fitness was not high enough to gain changes in aerobic performance. Conversely, in a study completed by Williams et al. (63) who investigated the aerobic responses in prepubertal children using high-intensity sprint running versus continuous cycling at 80-85% maximum heart rate. Both groups completed a pre-post motorised treadmill test to exhaustion to calculate their peak $\dot{V}O_2$ scores. The researchers reported no significant findings even with a training frequency of three-times a week over eight-weeks. The mean starting fitness level of the participants was extremely high (54.8 ml x kg^{-1} x min^{-1} ± 5.1) and the researchers used a motorised treadmill to test the participants peak $\dot{V}O_2$. As the participants demonstrated high levels of aerobic fitness, it may be difficult to gain further adaptations and if the participants were tested relative to aerobic performance, for example, the energy costs of running or changes in running economy, an aerobic performance may have been established. This emphasises that the intensity and frequency need to be considered relative to the starting fitness level and training background of young children, as peripheral adaptations may be a prerequisite to central adaptations. A benchmark of aerobic fitness may need to be established before changes in aerobic performance.

The importance of training intensity is well documented throughout the literature, irrespectively of the mode of training (3, 19, 52, 56). Baquet et al. (6) used running speeds, expressed as maximum aerobic speed (MAS) and reported aerobic improvements at intensities between 110-130% MAS. Williams et al. (63) employed running times between 10 and 30 seconds and instructed the participants to run as hard as possible. This is similar to this current study, as the participants in the SAI employed high levels of effort in their training sessions. The intensity in the SAI was measured using the OMNI scale, with the participants giving a verbal indication on their perceived effort level. Throughout the training sessions the participants commonly gave ratings of 7 out of 10 (7 = really tired), to 9 out of 10 (9 = very, very tired). Alternatively, the MA group performed a range of movement skills over the eight weeks including running, skipping, jumping and hopping. The games and activities were played at a high effort levels and the rest periods were a natural part of the game, as young children tend to play in this way (2). The rest periods accounted for when the ball was out of play or when, for example, a participant got tagged in an invasion game. Furthermore, the different ball games (dodge ball) exposed the children to a range of body control skills including stopping, change of direction, turning, twisting and dodging. The participants verbally perceived their effort level using the OMNI scale, after each mini-game, with the participants indicating an effort level from 6 out of 10 (6 = tired), to 9 out of 10 (9 = very, very tired). This would indicate that both the SAI and MA were performed at a high intensity level, and consistent with a training intensity threshold of 80% maximum heart rate or greater. The recommendation of starting the intensity at a high level may be misleading, however, as applying high intensities does not guarantee significant aerobic improvements, as Williams reported. Corte de Araujo et al. (12) reported aerobic fitness improvements and BMI changes using a continuous training approach with intensities up to 80% maximum heart rate, compared to high intensity training. Corte de Araujo did recruit obese participants, and their starting fitness levels were extremely low, around 30 ml x kg^{-1} x min^{-1}. As the starting fitness levels were extremely low, a training frequency of twice a week for 12 weeks was applied, as using a higher training frequency would increase their training volume. The reported average prepubertal aerobic fitness level is 44.7 ml x kg^{-1} x min^{-1} (7, 31), thus applying a higher intensity level may be applicable for children with high fitness levels, whereas reducing the intensity and applying a higher frequency for children with low fitness levels may aid in long term adherence rates.

Baquet et al. (7) reported an average training frequency was 3–4 training sessions per week, however, the authors stated that training twice a week may be sufficient to gain aerobic improvements. Berthoin et al. (10) reported aerobic improvements employing only one-training session per week over a 12-week period. There are noticeable similarities with this current study along with the training frequency. Berthoin reported a starting fitness level of 47.6 ml x kg^{-1} x min^{-1} compared to 48.21 ml x kg^{-1} x min^{-1}. Berthoin also reported an average aerobic improvement of 5.6%, compared to 5% improvements in this current study.

This implies that there should be training guidelines that highlight the appropriate intensity and frequency. A high intensity of 80% maximum heart rate or effort with a low training frequency seems to be effective for children with a high starting fitness level, however, the training volume may need to be manipulated to increase long-term improvements. A moderate to high intensity with a greater training frequency seems to be more effective for children with a low starting fitness level. This may help and support children who are overweight or obese to start a fitness programme, and not to be discouraged if changes in aerobic fitness are not immediate, as there still may be subtle aerobic improvements and changing the mode of training too quickly may not be advisable, especially if the children have a preference or enjoy it.

Social enjoyment and fun aspects to fitness especially when promoting fitness to younger children are essential. This was confirmed in a study completed by Howe et al. (23) where the energy expenditure and enjoyment factor of a range of games were monitored in 8–9-year-old children. The results of the study reported that from thirty different games, the games that were rated with the highest perceived enjoyment and fun factor, were tag and invasion games, where the children could move erratically and freely, i.e. playing rather than exercising. This further confirms that the mode of training should not be fixed or too structured when designing fitness activities for young children. As more children are becoming less active, this study amplifies that young children can improve either their aerobic fitness or performance through multi-activity games which can be fun, engaging and inclusive for all participants. Reverting back to basics and allowing young children the opportunity to play, to learn and to have fun, rather than trying to get them fit through repetitive exercises be it strength movements or long-continuous running. The specific training principle should be applied to, perhaps teenagers and adults when preparing for sport or a specific goal.

The results of this study provides some level of evidence to support the YDM, as the mode of training relative to aerobic adaptations seems to be less of a factor in the development of young children. The YDM recommends that young children should be exposed to a range of FMS and the concurrent training of the physical qualities of mobility, strength, agility and power. As this study concentrated on aerobic improvements, prescribing either multi-activity games or specific aerobic training are beneficial, however, prescribing multi-activity games exposures a greater spectrum of movements skills and is consistent with the YDM. The important considerations are based on the starting fitness level, training background and the skill level of the participants, as this will aid in prescribing the appropriate intensity, rest periods and frequency.

This study is not without limitations. The training frequency was low, with only one-session per week, however, prescribing a higher frequency would of be challenging within the school environment, as the school only allocates two PE lessons per week. The results of the study are consistent with Berthoin et al. (10) who also prescribed one session per week. However, a higher training frequency, the SAI may have shown superior improvements, as the SAI would possibly accumulate a greater aerobic training volume, therefore a clear limitation of this study was not monitoring volume rather than training frequency. Additionally, the intensity was measured using the OMNI scale, which is subjective and difficult to quantify. Implementing heart rate monitors to measure intensity and recovery would be ideal, however, this would be challenging when working with large classes. Lastly, the activity levels that the participants performed outside of the school was not accounted for and could have affected the results. By incorporating training diaries this would help to monitor overall activity levels and serve as educational for the participants.

PRACTICAL APPLICATION

This study should benefit PE teachers and other coaches who work with young children showing that aerobic training can be enjoyable and fun rather than repetitive and boring. To understand that young children can reap the rewards from playing games, from improving their aerobic fitness levels, along with learning the FMS, this will have long-term health, physical and social benefits. By allowing young children to move freely, to engage with their friends and to have fun, more children may start to increase their activity levels. However, the starting fitness level needs to be established, so the appropriate intensity and frequency can be applied. Further research needs to explore the optimal intensity and frequency for different starting fitness levels in young children.

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Appendices

A1. Participant Information Sheet

Study Title – **Comparing aerobic intervals and general multi-sport activities and their effect in improving aerobic performance in prepubertal children**

Purpose and value of the study

The purpose of this research study is to investigate the potential improvements in aerobic fitness in boys and girls aged between 8-9 years old by comparing specific interval type activity sessions and multi-sport sessions.

By completing this project (MSc in strength and conditioning), the results obtained through this study may help coaches and other professional sporting staff to understand the application of aerobic training with prepubertal children and their overall fitness development.

Invitation to participate

I would like to invite your child to take part in the research study. The study will explore the possible aerobic benefits and improvements surrounding different types of multi-sports and specific aerobic training games.

Who is organising or sponsoring the research?

The research is in conjunction with St Mary's University Twickenham and postgraduate researcher, Steve Wyatt, School of Sport, Health and Applied Science, MSc in Strength and Conditioning.

What will happen to the results of the study?

The data collected from the research study will be analysed, compared and used to form the final report. The results of the study will be made available to all participants along with feedback from the researcher.

Source of funding for the research

No expense or payment will be involved in the research study, as the study will be completed at the school. Additionally, the researcher will bring all appropriate equipment.

Contact for further information

You can contact the researcher Steve Wyatt on 07967441830 or 11581@live.smuc.ac.uk if you have any questions. The research study is in conjunction with the researcher's postgraduate MSc and a St Mary's research project.

Supervisor: Dr. Stephen Patterson

Email: stephen.patterson@stmarys.ac.uk

St Mary's University, Waldegrave Road, Strawberry Hill, Twickenham, London

Why has your child been invited to take part?

As the research study is investigating the aerobic fitness levels in prepubertal children within the ages of 8-9 years, your child fits this age range.

Can you or your child refuse to take part?

This is up to you and your child to decide and fully voluntary. Hopefully, this participant information sheet will answer all your questions. Should you have any further questions, please contact me. You and your child are free to withdraw from the study at any time, without giving a reason and will not be contacted again.

Can your child withdraw from the research project at any time? How?

If you or your child decide to withdraw from the research study you can send the researcher an email and all your child's personal information will be destroyed. You and your child will not be asked for a reason for withdrawing.

What happens if you and your child agrees to take part?

If you and your child decide to take part in the research study, your child will be involved in the below aspects:

a) At the start of the study, all children in the study will complete a 20-metre multistage shuttle run to calculate their aerobic fitness level. This is commonly known as the beep fitness test. The children will be coached and encouraged throughout the test and the children will work to their own fitness and ability level.

b) After completing the 20-metre multistage shuttle run, all children will have their height, body weight and body fat taken. These assessments are very simple to perform and noninvasive with the height being assessed via a height measure, and the body weight and body fat assessed by the children standing on scales.

c) The children will then be allocated to either the training group, sports group or a control group (regular PE). All groups; PE activities, multi-sports and training groups' will be coached through the sporting activities and games; however, the training group activities will be designed specifically to improve their aerobic fitness. All activities and sporting games will be designed to engage the children, so they enjoy and learn from the experience.

d) All children of the study will perform the 20-metre multistage shuttle run at the end of the study along with retaking the children's height, body weight, and body fat. The children's pre-and post-fitness levels will be analysed and compared.

Are there any risks involved?

There are none to minimal risks of taking part in the research study, as all fitness activities will be coached and supervised. The coach and researcher will also encourage all children throughout the 10 weeks so they fully engage, learn and enjoy the experience.

Will your or your child's legal rights be compromised if something goes wrong after agreeing to take part?

No.

Are there any special precautions that your child must take before, during or after taking part in the study?

There are no precautions that need to be taken before, during or after the research study.

What will happen to the information and data collected from your child?

The data that is collected throughout the reserach study will be used for this project only. All information will be kept confidential.

What are the possible benefits of your child taking part?

The main benefits from agreeing to take part in the research study is being a part of a supervised fitness activity programme, where all children will learn new activities and possibly improve their fitness level.

How long will the Project last?

The total research study will last 10 weeks. The below table illustrates how the 10 weeks will be managed in conjunction with the regular PE classes. All training sessions will be designed and fully supervisied to engage all of the children. The pre/post and training activities will be completed at your child's school.

Week number	Objective	Duration
1	Assessment of aerobic fitness, through beep tests. Collection of body weight, body fat, height and weight. Pre test collection	1hr
2 to 9	Trainining either in multi-sport games OR intreval aerobic games activities OR regular PE.	30mins per session
10	Assessment of aerobic fitness, through beep tests. Collection of body weight, body fat, height and weight. Post test collection	1hr

As the study will focus on the aerobic fitness improvements over ten weeks, if your child misses more than two PE activity sessions, your child and their data may be removed from the rest of the study.

How will your child's participation in the Project be kept confidential?

Your child's information will be kept highly confidential, stored on a password-protected computer accessed only by the researcher. Data protection Act 1998 will be adhered to.

All names and addresses will be removed so that you cannot be recognised.

The data collected from the study will be used for the final report and possibly future studies (up to 3 years).

No photographs or videoing will be completed within the research study.

A2. Informed Consent Form (Parent)

Name of Participant: ____________________________________

Title of the project: ____

Main investigator and contact details: __________________________________

Members of the research team:

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached top this form. I understand what my role will in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentially of the information I provide will be safeguarded.
4. I am free to ask questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data purposes connected with the Research Project as outlined to me.

Name of participant (print) ……………………………………………………………..

Signed ………………………………………   Date ……………………………………

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: ____

I WISH TO WITHDRAW FROM THIS STUDY

Name: ____

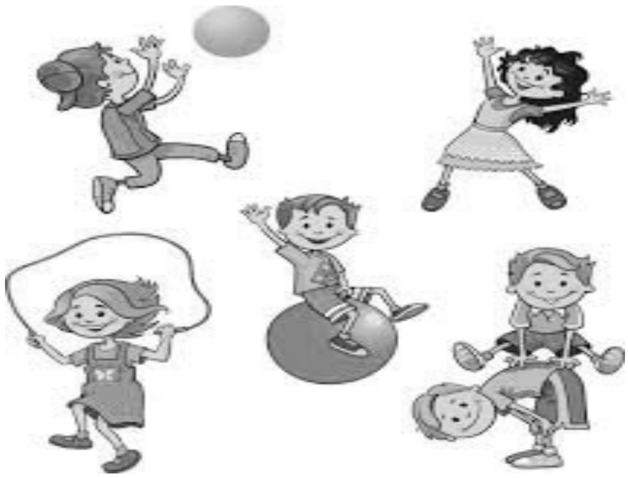
Signed: ________________________________   Date: ___________________________

A3. Informed Consent Form (Child)

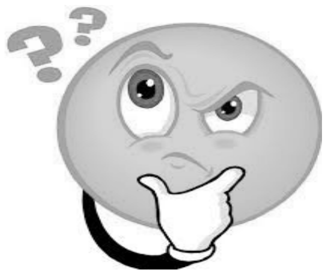
<u>Research Project</u>

My name is Steve Wyatt and I am collecting some information to be used in a project.

On a topic about fitness



I would like to ask you some questions about yourself and for you to take part in fun activities and challenges



The project will take place over the next 10 PE classes, where you will have fun, try your best and maybe become a litter fitter

During the PE classes if you're not sure about something or if you want to stop then just tell me

I will be recording and writing things down so I remember.

It is up to you if you would like to take part. If you do, please fill in the form below.

I would like to talk to Steve Wyatt about his project

Please write your name…………………………

<u>Please return this form to your teacher as soon as possible</u>

B1. Ethics Letter of Approval

St Mary's University Twickenham London

7 February 2017 Unique Ref: SMEC_2016-17_062

Steve Wyatt (SHAS): 'Comparing aerobic intervals and general multi-sport activities and their effect in improving aerobic performance in prepubertal children'.

Dear Steve

University Ethics Sub-Committee

Thank you for submitting your ethics application for the above research.

I can confirm that your application has been considered by the Ethics Sub-Committee and that ethical approval is granted.

Yours sincerely

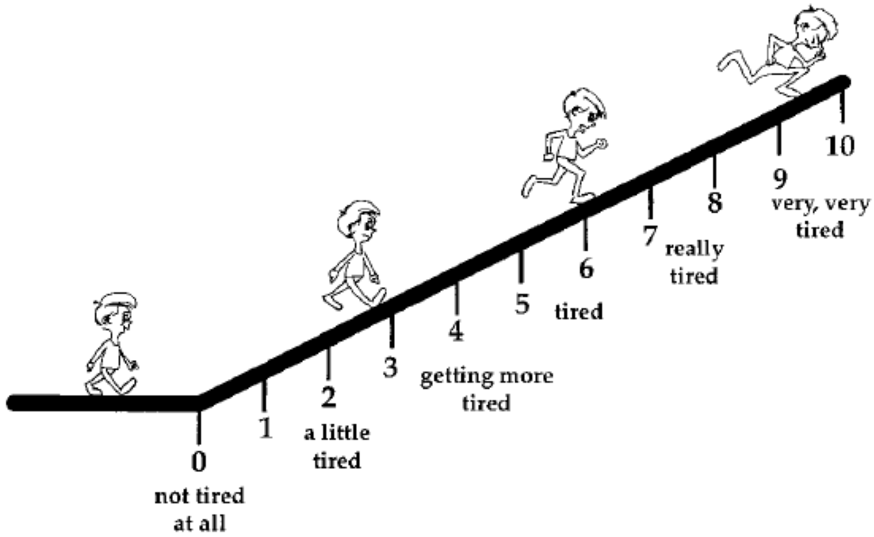
Conor Gissane

Prof Conor Gissane

Chair, Ethics Sub-Committee

Cc Dr Paul Read, Dr Stephen Patterson

C1. OMNI Rate of Perceived Exertion Scale



Children's OMNI Scale of Perceived Exertion for walking and running.

Utter, AC, Roberson, RJ, Nieman, DC, and Kang, J. Children's OMNI scale of perceived exertion: walking/running evaluation. *Med Sci Sport Exer: 34* 139-144, 2002.